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PATENT SPECIFICATION

707,060

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COMPLETE SPECIFICATION

Apparatus for the production of Polarized Light, particularly for Searchlights and like Illuminants

We, WALTER GEFFCKEN and HUBERT SCHRÖDER, both German Nationals, and both of 2, Niedermayerstrasse, Landshut, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

In a series of technical applications of polarized light, great difficulty arises in that, with the polarizers hitherto customary, only a fraction (theoretical maximum 50%) of the original light intensity can be utilized. If for example one wants to employ a searchlight with linear polarized light, or an anti-dazzle light source for vehicular traffic, then with the use of polarization films only about ⅓ of the original light intensity is radiated, so that after passage through the analyser goggles, placed in parallel position, only about 20 to 25% of the original light beam reaches the eye; the remaining energy is absorbed in the polarization films and is lost as heat. Avoidance of such losses has, in fact, been possible with the old glass plate set, but a very large number of glass plates was necessary and the successively reflected components were split up into a correspondingly large number of partial beams of diminishing intensity. To be sure suggestions have been made to utilize all of these partial beams and to direct them into a common vibration plane, but these however have never been practically utilized because of the low efficiency and unwieldiness of the said glass plate set.

So-called "interference polarizers" are already known which consist of a plurality of alternate layers of high and low refractive index located between prismatic transparent bodies, and which transform practically the total incident light into only two partial beams differently polarized and proceeding in different directions. Such an interference polarizer represents, so to say, a micro glass plate set, which is free from the drawbacks of the old glass plate set and far excels it in efficiency. It is further known to make both said components simultaneously effective, whereby e.g. a rotation of the vibration direction is attainable for the second (reflected) component, by means of an inserted doubly refracting plate, which component is then deflected by means of a second polarizer into the same direction of propagation as that in which the first component passes through the first polarizer.

These proposals are applicable only for light beams of moderate cross section, since otherwise, as can be easily understood, very large and thereby heavy and expensive prisms result.

The present invention is concerned with improvements in such known arrangement, making it applicable for lights of large area, e.g. searchlights. To that end the invention provides a polarised light source such as a searchlight, comprising a lamp, systems of beam splitting polarizing interference layers (as herein defined) cemented between prismatic transparent bodies to form a compact body presenting parallel faces to all light rays travelling through said body and dividing the light beam into two components vibrating at right angles to each other, phase retardation means for rotating the vibration plane of the one light vibration component into that of the other, and means for deflecting the separated component into the original direction of the light beam from said lamp.

For deflecting the separated components back into the original direction of the beam, the following possibilities were found in principle. Firstly, one can effect

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such deflection, as in the arrangements hitherto known, but with consequential increase in the width of the beam. This often undesirable increase of the lamp cross section can, in accordance with a further feature of the invention be avoided, if one, secondly, deflects the said component back into the lamp space by way of a phase retarder and therewith increases the effective radiating light source. The last mentioned method can be understood as follows. As is known, the illumination field of a searchlight is an image of the light source, magnified in proportion to the focal length of the mirror used therewith. In the present case this source consists not only of the actual light source, but also of its image produced by the deflection back into the lamp space. Thereby, through appropriate optical accessory means, one can make the light source and its image of equal or different size in the illumination field. Appropriately one will so adjust the light source, that its image immediately adjoins it, since it is desirable in a searchlight to concentrate the luminosity upon the smallest illumination field possible. In the special case, where the image of the light source coincides with the source itself, an increased temperature of the radiant results, with the same energy input.

In the accompanying drawings Figs. 1 and 2 show solutions of the just described case of the deflection back of the reflected component, Fig. 1 for an arrangement with condenser lens (2), Fig. 2 for a searchlight with paraboloid mirror (3). In both cases approximately parallel light arrives from the light source 1 upon the interference polarizer, which consists of the two prisms 4 and 4^1, between which are the alternatingly high and low refracting polarizing layers 5 in such manner that for the rays falling upon said layers at the angle of incidence α, the relation holds:

$$\sin^2\alpha \geq \frac{n_h^2 \cdot n_1^2}{n_g^2(n_h^2 + n_1^2)} \qquad (1)$$

(n_h = refractive index of the high refracting layers of the polarizer, n_1 = refractive index of the low refracting layers of the polarizer, n_g = refractive index of the glass bodies). Half of the light, namely the component vibrating in the plane of the drawing, passes rectilinear through the polarizer, the other perpendicularly vibrating component, is reflected and strikes the mirror 8, which deflects the rays back into the lamp space along approximately the same path where in Fig. 1 they unite on a reflector 9, and in Fig. 2 form a real image of the light source at 1^1. The broken lines refer to the rays departing from the mentioned images of the light source, whereby the divergence is drawn strongly exaggerated for the sake of clearness. A phase retarding plate 10 is located between the polarizer and light source, which plate therefore is always passed twice by the reflected component, so that its vibration plane after the second passage, when it is a matter of an appropriately oriented $\lambda/4$ plate, is rotated by 90° from its original vibration plane.

If the reflection of the reflected component—as e.g. with employment of a parabolic mirror—occurs repeatedly and under increasing angles of incidence, then it can be appropriate, for elimination of the supplementarily effected elliptic polarization, to employ in place of the $\lambda/4$ phase plate, a lamina of other phase difference which is best determined experimentally for the given system.

With the described arrangement one achieves in consequence of the repeated filtering of the one component a high degree of polarization; however on the other hand it also carries the disadvantage with it, that the repeated metallic reflections, as well as the supplementary phase retardations induced by them, which under the circumstances can not be completely eliminated over the entire field of view, can yield losses.

These can be eliminated with the parabolic mirror, at least in part, if one develops the mirror 8 as a cylindrical concave mirror 11 (Fig. 3) whereby the reflected radiation is concentrated upon a convex cylindrical mirror 12 of suitable focal length with a $\lambda/4$ platelet 13 placed before it, which mirror 12 again throws the reflected radiation upon the polarizer approximately parallel and rotated in its plane by 90°. In order to avoid a loss in consequence of shading of the lamp by the mirror 12 one suitably inserts between them a small spherical mirror 14—usually already installed in searchlight lamps—which deflects the radiation of the lamp in the concerned sector to the seachlight mirror.

Figs. 1—3 merely illustrate the problem as so far discussed. The remaining Figures illustrate the invention. The methods so far described of utilizing the second component gain considerably in practical significance, if one splits up the interference polarizer into a system of individual polarizers with the polarizing layers arranged in a common plane. An execution form for such a system is

represented in Fig. 4. It consists of a series of suitably equal sized individual polarizers 20, which are ranged against one another with the edges cut by the polarizing layers 21, so that the layers together form a continuous surface 22. The production of this system appropriately is effected thus; the flat surfaces of two glass plates, each plate being ground or pressed to a stepped formation on the other side, are joined together after one has coated one (or both) flat surfaces with the polarizing layers. In general one will aim, either through the shape of the searchlight mirror 3 or with aid of condenser lenses, to have parallel light passing through the polarizer plates, so that the surface 22 is a plane; however one can also develop such polarizers for divergent light, in that one gives such a curvature to the surface 22 that the incident rays all cut it at the angle α, for which the relation (1) mentioned above holds.

Thereby one will also so place the stepped surfaces 23 and 23^1 that the transmitted rays are parallel to them, and place the surfaces 24 and 24^1 in such a way that they stand perpendicular to the arriving or departing rays. Further, the surfaces 23 and 23^1 may lie in the same planes in order that the total field of view is not too frequently interrupted, however this condition is not absolutely necessary. The stepped polarizers according to Fig. 4, for utilization of the reflected component, can be combined with all of the previously described kinds of deflection and rotation of this component. In Fig. 4 the case is illustrated in which the reflected polarized component is deflected back into the lamp space by means of the mirror 8 and rotated by means of the phase plate 10. With a curved surface 22 one will also curve the mirror 8 so that the incident rays will as far as possible again be deflected back upon themselves If on the other hand one constructs the stepped polarizer of two parts lying symmetrically to one another, whose layers in the plane of incidence intersect at an angle of approximately 90° (Fig. 5), then one has the advantage that the mirror 8 is unnecessary, since now the deflection back takes place at the polarizers themselves; besides a considerable saving in space results.

The principle of the stepped polarizers can also be reversed in that one produces the polarizing layers, as Fig. 6 shows, in the form of steps or **V**-shaped corrugations, whereby the individual corrugation faces are alternatingly inclined approximate ±45° to the incident ray direction. Thus two neighbouring corrugation faces together form an angle of about 90°, so that a ray falling upon a corrugation face after reflection at this and the neighboring face is thrown back in its original direction. Appropriately the corrugated polarization layer is produced thuswise that one applies the layers to a suitably formed transparent support and then either fills the corrugations with a transparent material or cements a second body, ground or pressed into a suitable shape, into the corrugations. If desired also this second body can carry polarizing layers. Thereby it is to be recommended to so develop the complete system that outwardly it equals a plane parallel plate (Fig. 6). In order not to have the image of the light source produced by such a polarizer in the lamp space coincide with this light source itself, one must let the rays be incident slightly inclined to the transverse median plane of the corrugation faces.

Utilization of the second component with such like polarization systems can also be accomplished according to a further procedure in accordance with the invention. This requires that one restricts the entrance of the primary unpolarized radiation into the polarizer system, to band shaped surfaces separated from one another, whereby these surfaces also in their projections upon a plane perpendicular to the direction of the arriving rays are separated by interspaces. Carrying out of this principle with the stepped polarizer can e.g. be realised by giving the prismatic plate first struck by the rays the form drawn in Fig. 7. The surface 25 blocking the entrance of light lies parallel to the layers 21 and is made reflecting to the outside and to the inside. The light entering through the surfaces 24 is in part transmitted by the layers 21 in part thrown upon the mirror 25, in front of which is advantageously also mounted the rotation producing phase plate 30. Its phase difference is so regulated that it together with that effected by the reflection for the twofold passage amounts to exactly $\lambda/2$. The reflected and rotated component can then pass through the layers 21 and leave at 24^1 together with the transmitted component. The light falling upon the surfaces 25 can either fall by way of a mirror 26 placed parallel to the layers 21 upon a continuation of the same stepped polarizer or upon a similar polarizer system, or one employs such a system in place of mirror 26.

While the just described execution form is perforce connected with a doubling of the cross section of the beam, such can be circumvented by a further

solution in accordance with the invention, which likewise depends upon the principle of the restricted entrance surfaces. It is distinguished from the preceding execution of the stepped polarizer thereby, that on the surface 25, which now need be metallized only on the glass side, prisms are cemented, whose cathetus surfaces coincide with the planes 23 and 24. The surfaces coinciding with 24 are metallized, so that the light falling upon them again arrives back into the lamp space.

Self-evidently the deflecting back into the lamp space can also be effected by a glass plate metallized in bands, and placed perpendicular in the beam.

The deflection of the incident rays by reflection from the metallised surfaces, which unavoidably is connected with certain losses, can be completely circumvented by a further solution of the problem likewise belonging to the invention. One inserts for this purpose in the ray space of the parallel searchlight beam a telescopic - cylindrical imaging system which effects a periodic constriction of the beam cross section on the entrance surfaces of the polarizer elements. This can be realized e.g. in the manner that one (cf. Fig. 8) employs a system of positive band shaped cylinder lenses 31 arranged in a row in contact with one another, in suchwise that the width of a cylinder lens is twice as large as the width of the entrance surfaces of the polarizer elements, and that the median plane of each cylinder lens band coincides wih the median plane of an entrance surface. At a distance of half the focal length of this system, is located a further negative lens system 32; the rays again made parallel thereby enter adjoining into the entrance surfaces of the polarizer system. For the aperture of the lens screen a ratio of about 1 : 10 is recommended. With this arrangement is achieved that one can polarize the total radiation without change of the normal light beam cross section and well-nigh without loss.

The two cylinder lens systems can also be formed together as a single body, about after the fashion of Fig. 9, which then can be produced especially simply by pressing of glass or synthetic material.

The stepped polarizers indeed possess an excellent efficiency; they have however the disadvantage that they are expensive with precise execution of the stepped surfaces, whereas a less exact execution easily leads to scatter losses. These disadvantages drop out in a further execution form of polarizer systems in accordance with the invention, which in addition combines the advantages of a small space requirement, externally smooth surfaces, and simple manufacture.

The principle of this type of polarizers is represented in Fig. 10. Between the parallelepiped shaped prism bodies 33 lie the polarizing layers 36 and 36^1 ever equidistant and parallel to one another, and the distances between which are so maintained that the projections of the layers on a plane perpendicular to the passing rays join one another without gaps. Thereby they can also mutually overlap (Fig. 11), which can entail the advantage that the degree of polarization is still considerably increased. The light entering through the surfaces 34 (Fig. 10) passes with the one component through the layer 36 and again leaves at the surfaces 35, the other component vibrating perpendicular thereto is reflected by layer 36 upon the neighboring layer 36^1 and by this again deflected into the original direction, so that it leaves at surface 37. Here it is also rotated by 90° in the vibration plane by a $\lambda/2$ phase platelet 38. The surface 34 is appropriately blackened behind the layer 36^1 to intercept possible interfering light. In order to fully utilize the lamp radiation one must therefore merely see to it that the light falling upon the surfaces 39 is likewise utilized. This again can be attained according to the procedure described in connection with the stepped polarizers, in that one either metallizes the surfaces 39, or inserts a band wise metallized plate placed obliquely into the beam before the polarizer system or employs a cylinder lens system in the above indicated manner for constricting the beam on the passage surfaces 34.

If the beam to be polarized is not parallel, then one obtains with the described equidistant polarizer system light either partly unpolarized or not appropriately polarized light. In this case it is possible to so construct the cemented prism system, that in a section, observed parallel to the plane of incidence (Fig. 12), the limiting surfaces of each polarizer element stand perpendicular to the transmitted rays and the parting planes containing the polarizing layers are ever struck in their middle by the arriving rays at an angle of α, for which the relation (1) shall hold. However, one can also, if one does not want to give up the parallelism of the prism surfaces, proceed thus that one no longer arranges the polarizing layers equidistant, but at such intervals that the transmitted beams just fully illuminate the total polariz-

ing layer system (Fig. 13). The representation of Fig. 13 is diagrammatic and disregards the refraction of the rays in the prism body, so that also the changes of the angle of incidence for the layers can be kept within the validity limits of equation.

In the application of unfiltered incandescent light and visual observation one will so regulate the thickness of the phase platelets, that the desired phase retardation will occur for the maximum of the spectral visual sensitivity curve, therefore at $\lambda = 555$mu. In the arrangements hitherto described, in which the phase plate is traversed after the exit from the polarizing system, as e.g. in Figs. 10, 11, 12 and 13, one will therefore be able to achieve no completely linear polarization for the rotated component in the spectral regions further removed from λ so that with a crossed analyser one observes therefore in this case a faint violet to purple coloured residual light. In order to exclude also this residual light when especially high purity of the polarization is necessary one can still improve the above arrangements in accordance with the invention thereby, that one adds a further polarizing system, for which an execution example is represented in Fig. 14. Herein 36 and 36^1 signify the polarizing layers of the first polarizing system, 38 the $\lambda/2$ phase plates, 36a and $36a^1$ the layers of the supplementary polarization system. The surfaces 41 and 42 are appropriately blackened; 40 can be metallized or blackened over according to the illuminating system. The polarizing layers 36a are as such unnecessary and can indeed be omitted.

The prism surface 42 which increases difficulty of manufacture can be circumvented, if one uses the solution illustrated in Fig. 15. The radiation arriving through the entrance surface 34 is divided by the layer 36 into the parallel and vertical component, of which the first, rotated by the $\lambda/2$ phase platelet 38, falls upon the polarizer 46, whose back 47 is blackened; from here it leaves the arrangement after reflection at the opposite lying polarizer 46^1. The other (vertical) component is reflected solely at the polarizers 36 and 36^1 and then proceeds parallel and unidirected with the first component. One of the surfaces 46 and 46^1 can here naturally also be replaced by a customary metallic reflecting layer (46a Fig. 16). If on the other hand one replaces the polarizer 46 by such a reflecting layer, then one can also arrange the phase plate 38 lying parallel before this (Fig. 16), then however one must choose the phase retardation thus that it together with that effected by the mirror in the hither and thither passage through the plate amounts to exactly $\lambda/2$. In the latter case one can also combine the two polarizer systems into a joint system, in that one employs polarizer elements according to Fig. 17, whose polarising layers 36 and 36^1 run through continuously and in their projection perpendicular to the ray direction even mutually overlap by a half, while the (likewise continuously running through) metallized layers, blackened layers, and phase platelets in the same projection precisely join one another. The layers 36 lying behind the light entrance surface 34 are thus on the one hand adjacent to the layers 36^1 with the blackened layer 47, on the other hand to the phase plates 38, which backwards border on the metallized layer 46a. Directly on the back of the metallized layer 46a lies the blackened layer 47 of the next element.

The two last solutions, especially that represented in Fig. 17, are of special advantage for manufacture; namely it is to be recommended to produce the polarizing systems of Fig. 10 to 17 in the fashion that one hard cements as many plane plates as the completed system shall contain individual elements, after coating them with the polarizing layers, and then cuts them in the required oblique direction into plates of the desired thickness and polishes the cut surfaces (Fig. 18). Finally, for elimination of strains, one still subjects the entire body to a heat treatment with slow cooling according to known rules. If now in the execution of Fig. 16 or 17 one places the phase plate 38 parallel in front of the metallized layer 46a applied as substitute, then in manufacture one can coat the entire plates with the phase retarder film, metallize blacken, and then cement. Therewith the difficult adjustment labour drops out which is required for placing the phase plates in the plane 44—45.

Suitable for building up of the polarizing interference layers are, as is known, e.g. silicic acid, alkaline-earth fluorides, or cryolite for low refracting, sulfides of zinc or cadmium, heavy metal chlorides as lead chloride or thallium chloride, as well as metallic oxides, such as those of titanium, antimony, or tin for high refracting layer material, whereby the application can take place in known manner either *in vacuo* by vaporization or sputtering, or by precipitation from colloidal liquid or gaseous phase. The linear polarized partial beams, which one layer materials, can naturally also

be transformed into circular or elliptic polarized radiation by the addition of suitably oriented λ4 platelets. This is of particular importance for fog searchlights, in which, as is known, the back scattering can be greatly reduced by use of circular polarised light.

The above mentioned dependence of the phase retardation on the wave length, which at the ends of the spectrum can lead to a departure from the linearity of the polarization, can however be utilised conversely also. If one selects for linear polarized light e.g. phase retarders of higher order (thus $3\lambda/2$, $5\lambda/2$, etc.) then the spectral region of adequate linearity becomes ever narrower, between which lie regions of elliptic or circular polarization. If one takes by way of example a phase retarder of $7\lambda/2$ for $\lambda=550$ mμ, then this acts as a phase retardation of $5\lambda/2$ at 770 mμ and of $9\lambda/2$ at 430 mμ. At these three places therefore the light would be completely extinguished by a crossed analyser, at $\lambda=640$ or 480 mμ (phase retardation $=3$ or 4λ), on the other hand only an extinction of the one component would take place, since the other would not be rotated; at all other places of the spectrum one would have on the other hand elliptic or circular polarized light. The color effects brought about thereby can find application say for signalling purposes.

For phase retarders one takes most conveniently crystal-clear organic materials, which during manufacture are exposed to a directed tension, e.g. films of cellulose ester, polyvinylalcohol or the like.

Strainless glass of optional kind is suitable material for the prisms of the polarizer layers, whereby the relation (1) is always to be considered.

What we claim is:—

1. A polarized light source such as a searchlight, comprising a lamp, systems of beam splitting polarizing interference layers (as herein defined) cemented between prismatic transparent bodies to form a compact body presenting parallel faces to all light rays travelling through said body and dividing the light beam into two components vibrating at right angles to each other, phase retardation means for rotating the vibration plane of the one light vibration component into that of the other, and means for deflecting the separated component into the original direction of the light beam from said lamp.

2. A polarized light source according to claim 1, in which said rotating and deflecting means is constructed and arranged to deflect the one polarized partial beam of each polarizer by way of a phase retarder back into the lamp from whence, after a further passage through the phase retarder it returns to the polarizer system.

3. A polarized light source according to claim 2, in which said rotating and deflecting means is so constructed and arranged that the image of the lamp formed by the deflecting back of the partial beam lies directly beside the lamp itself.

4. A polarized light source according to any preceding claim, in which the polarizing layers in the interference polarizers are stepped like V-shaped corrugations, and wherein the individual corrugation faces alternately are inclined approximately ±45° to the incident direction of rays.

5. A polarized light source according to claim 4, in which the said polarizing layers are applied on corrugated pressed or ground surfaces.

6. A polarized light source according to claim 1, in which the polarizer system is so constructed that the entrance of unpolarized radiation into such system is restricted to band-shaped surfaces separated from one another.

7. A polarized light source according to claim 6 in which the surfaces of the polarizer system lying between the said band-shaped light entry surfaces are metallized on the surfaces facing the lamp.

8. A polarized light source according to claim 6 or 7, in which the surfaces of the polarizer system facing the lamp and lying between the said band-shaped light entrance surfaces of the individual polarizer elements are provided with metal layers arranged in bands and placed perpendicularly to the beams to throw them back into the lamp.

9. A polarized light source according to claim 6 or 7, in which the surfaces of the polarizer system facing the lamp and lying between the band-shaped light entrance surfaces of the individual polarizer elements are provided with metal layers placed obliquely to the beams to deflect them and allow them to be polarized separately.

10. A polarized light source according to claim 6 in which a telescopic-cylindrical imaging system is inserted in the beam between the radiation source and the polarizers to effect a constriction of the beam cross section on the band-shaped entrance surfaces of the polarizer elements.

11. A polarized light source according to claim 10, in which said imaging system is composed of a positive cylinder lens system whose construction corre-

sponds to that of the polarizer system, and a negative lens system of half focal length of the positive system behind which it is located at a distance equal to half the focal length of the said positive system to re-impart to the rays their parallel direction.

12. A polarized light source according to claim 11 in which said cylinder lens systems are united together into a single, preferably pressed, body of transparent material.

13. A polarized light source according to claim 1 in which the limiting surfaces of each polarizer element stand perpendicular to the transmitted rays and the polarizing layers of each element everywhere are struck at an angle α for which

$$\sin^2\alpha \geq \frac{n_h^2 \cdot n_l^2}{n_g^2(n_h^2 + n_l^2)} \quad \text{holds.}$$

wherein n_h, n_l and n_g are the refractive indices of the high refracting layer, the low refracting layer and the glass bodies respectively.

14. A polarized light source according to claim 6, with which is combined a second polarizing system, of a similar kind and in which said second polarizing system is arranged in series behind the first polarizer.

15. A polarized light source according to claim 6, with which is combined a second polarizing system of a similar kind, in which the said second polarizing system is arranged in series behind the first polarizing system and so that rays are reflected substantially unaffected by the polarizing layers of the said second polarizing system, whereas the small residue of the light component vibrating parallel to the plane of incidence passes through and is eliminated by absorption.

16. A polarized light source according to claim 14 or 15 in which the polarising layers of the said second polarizing system are arranged at twice the distance of those of the first polarizer system, each of said systems having between the outer layers thereof a layer impervious to rays.

17. A polarized light source according to claim 16 in which one of the polarizing layer systems adjacent to the opaque layer in each system is replaced by a metallic reflecting layer.

18. A polarized light source as claimed in claim 17 in which the phase retardation plate is placed parallelly in front of the metallic reflecting layer and the phase retardation is so adjusted to the optical characteristics of the reflecting layer that the phase retardation effected by the phase plate and the reflecting layer together amounts to exactly $\lambda/2$.

19. A polarized light source as claimed in claim 17 in which the said second polarizer system is united together with the original polarizer system into a single system with continuous glass bodies and layers for polarization, phase retardation, reflection, and ray absorption.

20. Light sources substantially as herein described with reference to and as illustrated in Figs. 4—18 of the accompanying drawings.

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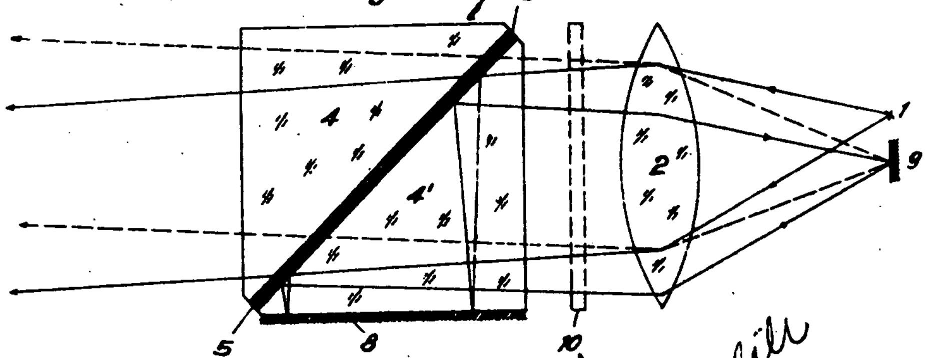
Fig. 1



retard. plate

Fig. 2

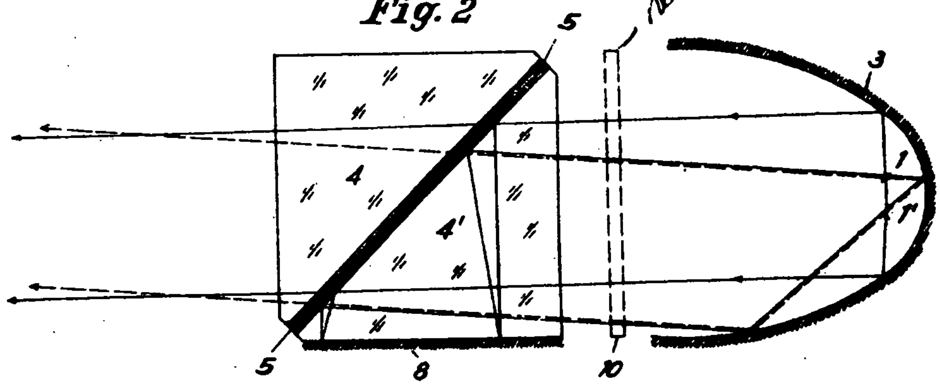
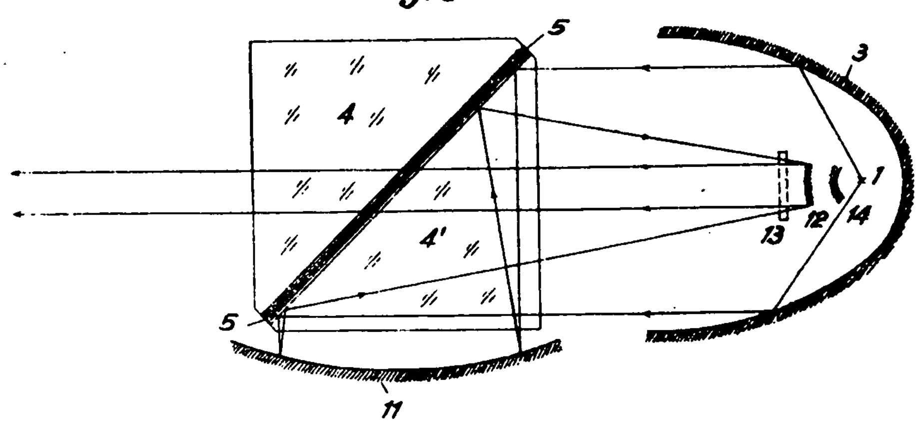


Fig. 3



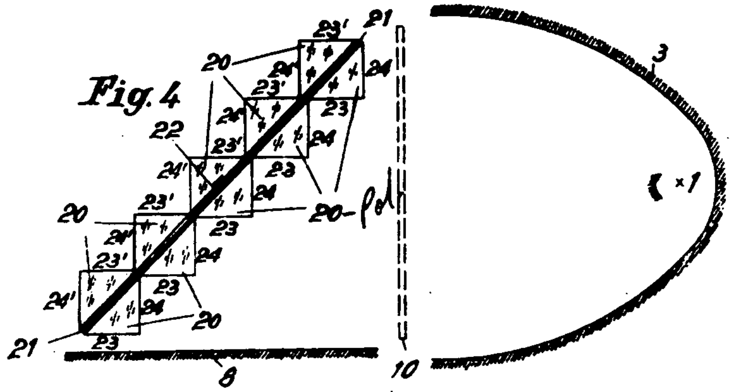


Fig. 4

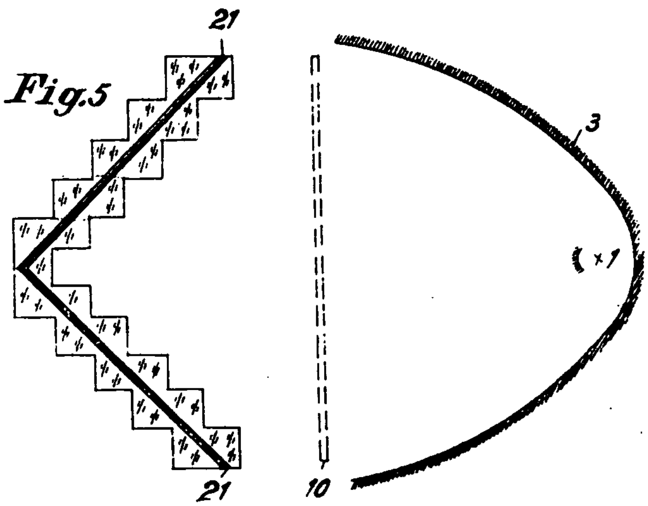


Fig. 5

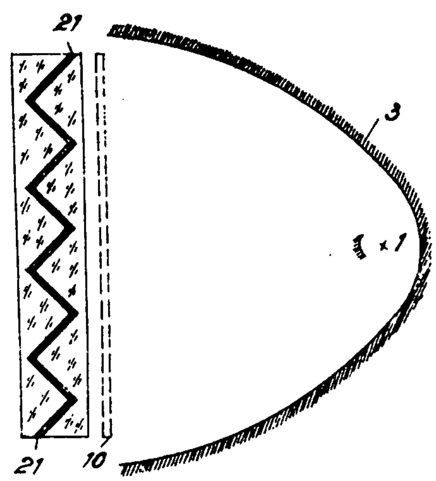


Fig. 6

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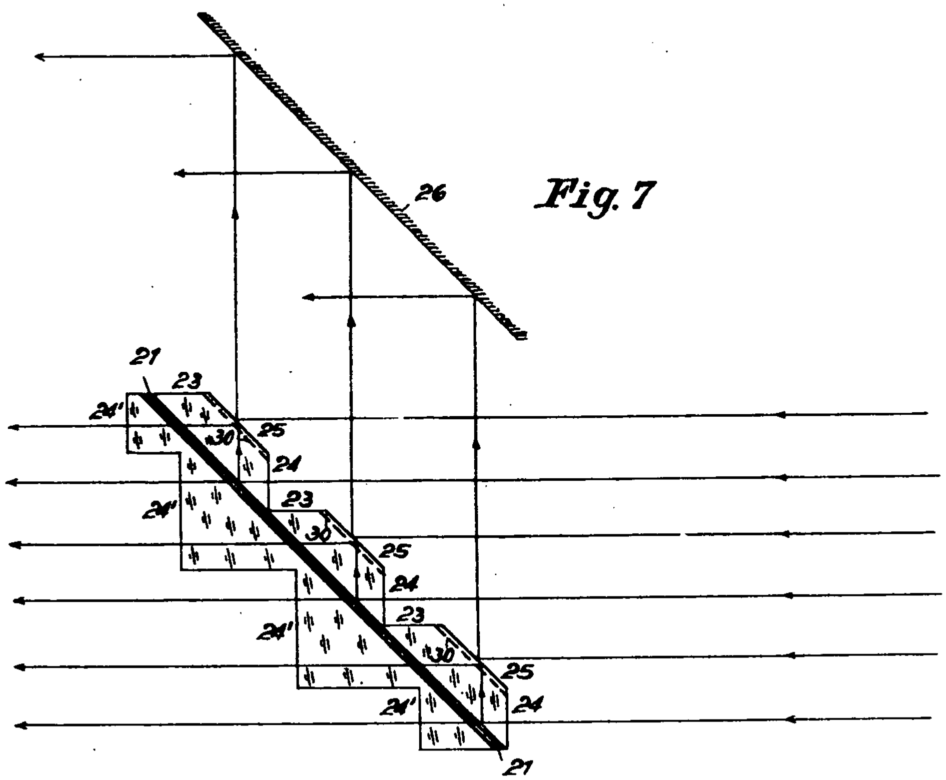

Fig. 7

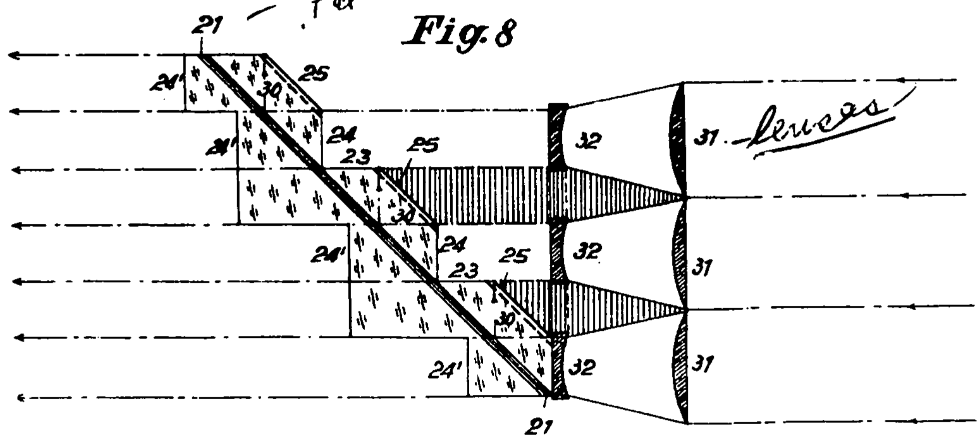

Fig. 8

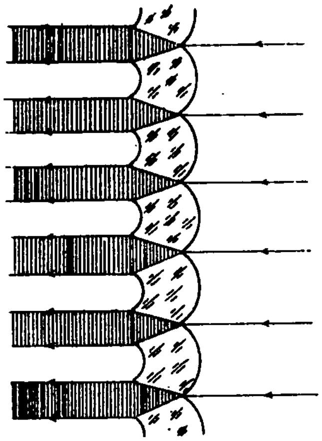

Fig. 9

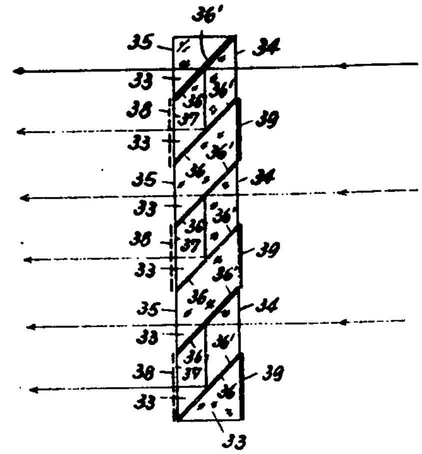

Fig. 10

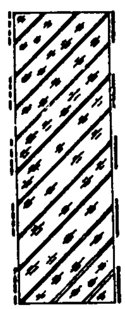

Fig. 11

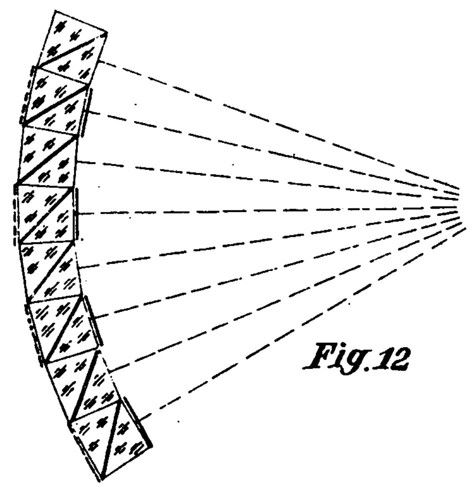

Fig. 12

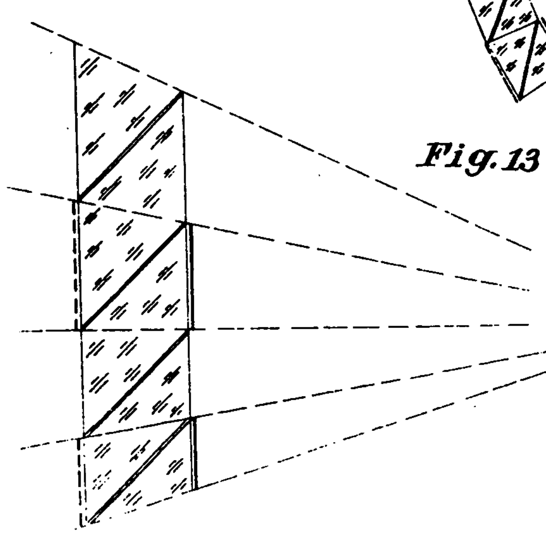

Fig. 13

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5 SHEETS *This drawing is a reproduction of the Original on a reduced scale.*

SHEETS 4 & 5

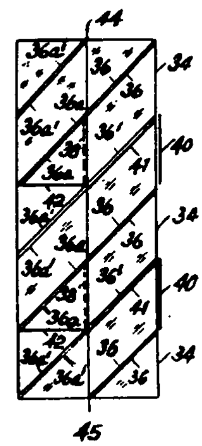

Fig.14

Fig.15

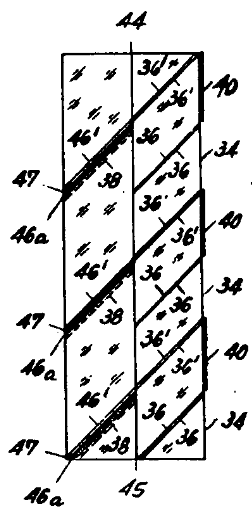

Fig.16

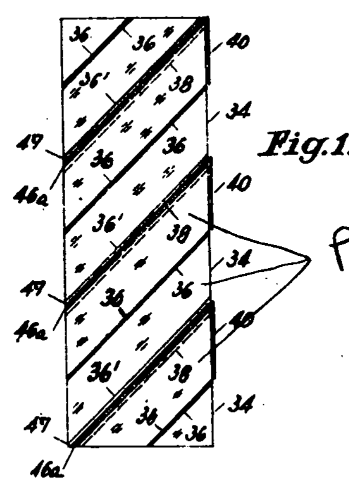

Fig.17

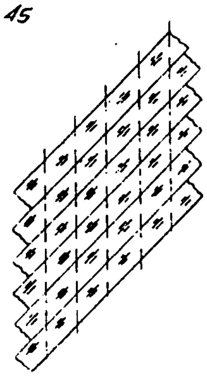

Fig.18